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AEM (ARSENAL EXCHANGE MODEL)/SOSAC EXPANSION
MODIFICATION AND MAINTENANCE(U) SCIENCE APPLICATIONS
INC ENGLEWOOD CO 27 APR 82 SAI-82-007-DEN
F49620-81-C-0095

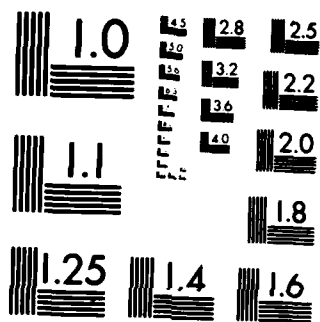
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AEM/SOSAC EXPANSION MODIFICATION
AND
MAINTENANCE

A FINAL REPORT ON CONTRACT NUMBER
F49620-81-C-0095

Prepared for :

Headquarters United States Air Force
Assistant Chief of Staff Studies and Analyses (SASF)
The Pentagon, Washington, D.C. 20330
Under Contract F49620-81-C-0095

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Section 1 INTRODUCTION

This report summarizes the work accomplished under Contract Number F44620-81-C-0095. The work described was produced over a period of 10 months. Approximately half of the effort was performed as a subcontract to Science Applications, Inc. by The Stonehouse Group, Inc.

The work accomplished falls roughly into the following categories:

- 1) Expansion of the AEM dimensions.
- 2) Incorporation of accounting hedges into the AEM.
- 3) Incorporation of the capability for the user to specify strategies for the allocation process in the AEM.
- 4) Providing general training, maintenance and data base support for the AEM, PACER, GROSA and SOSAC models.

The statement of work, as it appeared in the contract, is presented in Section 2 (Statement of Work).

Work performed in each of these areas will be specifically covered in Section 3 (Description of Work Accomplished).

A list of references associated with this work appears in Section R at the end of this document.

Section 2
STATEMENT OF WORK

The statement of work, as it appeared in the Stonehouse Group, Inc. subcontract and the statement of work as it appeared in the Science Applications, Inc. contract, are presented here for reference. Note, that the statements of work are identical for Tasks 2.1, 2.2 and 2.3 and that Task 2.4 is missing from the Stonehouse Group, Inc. statement of work.

SAI/GOVERNMENT
STATEMENT OF WORK

1. Objective: The objective of this effort is to improve the quality and efficiency of AF/SASF strategic analyses by modifying the Arsenal Exchange Model (AEM) to process problem statements of increasing scope and detail and expanding analyst control over allocation and output processes.

2. Tasks: In pursuit of this objective, the contractor will perform the following tasks:

- 2.1. Expand the maximum permissible number of weapon classes, hedges and target classes in the AEM to 50, 40 and 400 respectively. This task must be accomplished without adversely affecting the run-time efficiency of the AEM.
- 2.2. Incorporate into the AEM an accounting facility which allows the user to create or define the same type of output summaries as can currently be created or defined using the AEM hedging capability. This new accounting facility will utilize formats similar to the existing hedge facility; will be completely separate from the existing hedge facility, to the extent that it will not affect the allocation process; and will permit specification of up to 100 accounting requests.
- 2.3. Expand the AEM to allow the user the option to completely specify the set of targeting strategies to be presented to the allocation process. In addition, unambiguous constraints should be resolved prior to entering the linear programming portion of the allocation process. The specification methodology should be similar to the process used by the SWADE model. Output routines should be modified to indicate the permissible strategies resulting from the intersection of specifications via this facility with those of all other strategy specification facilities. In particular, hedge specifications that are unattainable because of conflicting specifications should be identified, to the extent possible, in the output print. The contractor must receive TRCO approval of the proposed implementation of this task prior to actual implementation.

- 2.4. Provide general training, maintenance and data base support for the AEM, PACER, GROSA and SOSAC models. The TRCO will request support on an "as needed" basis. the man-hours associated with this task will not exceed 450 hours.

3. Software, Documentation and Progress Reports:

- 3.1. The contractor will deliver software for Tasks 2.1 and 2.2 within six months of contract initiation.
- 3.2. The contractor will deliver software for Task 2.3 within nine months of contract award.
- 3.3. The contractor will update the current documentation to reflect all changes and enhancements developed in support of this effort. Documentation will be prepared in accordance with "AF/SA Guidelines for Documenting Computer Simulation Models", January 1981. The TRCO will provide this manual to the contractor.
- 3.4. The contractor will deliver written monthly progress reports to include, at a minimum, 1) progress toward completion of specific milestones; 2) level of effort to date and projected for the coming month; 3) cumulative cost and projected funding for the coming month; 4) deviations from the task schedule; and 5) status with respect to contract objectives.
- 3.5. A final technical report will be delivered at the end of the performance period summarizing the effort.
- 3.6. The contractor will submit a completion plan for the contracted effort as part of his first monthly program progress report.

4. Compatibility With Current AEM Capabilities: In accomplishing the tasks described in paragraph 2., the contractor is not required to insure that the options listed after the SOW are working. However, the basic code for the options should either remain in the AEM or be removed in modular form so that, if the need arises, minimal effort will be required to adapt the obsolete options to the modified AEM. Aside from these exceptions, all tasks will be accomplished without degradation of the current AEM capabilities.

5. Verification: The following verification procedures will be used to determine whether or not the tasks described in paragraph 2 have been satisfactorily accomplished:

- 5.1. Initial verification of successful accomplishment of Task 2.1 will include evaluation of the results of at least two, but no more than eight, test cases designed to test the expanded weapon/target/hedge handling capabilities of the AEM. The contractor will design the test cases by expanding, through duplication or subdivision, the number of weapon and target classes from one or more base cases provided by the TRCO. Verification requires that the solution for each test case be the same as that of the base case from which it was generated. The TRCO will design the base cases to exercise the expanded hedge capacity. In order to verify that capacity expansions have not adversely affected model efficiency, the CPU time required to process the base cases on the upgraded version of the AEM must not exceed the time required by the original (or pre-upgrade) version.
- 5.2. Initial verification of successful accomplishment of Task 2.2 will require using the new accounting facility to produce summary output identical to that producible using the current hedge facility. Working with the TRCO to design appropriate test cases, the contractor must also demonstrate the capability to simultaneously honor up to one hundred accounting requests.
- 5.3. Initial verification of successful accomplishment of Task 2.3 will include at least two test cases demonstrating general allocation control, cross targeting and unambiguous constraint resolution. The contractor will provide the test cases which will be subject to TRCO approval.
- 5.4. Verification of Task 2.4 will be accomplished by the TRCO through review of the monthly status reports provided by the contractor. The TRCO will check for consistency between services provided and work claimed.
- 5.5. It is virtually impossible to test new features under all possible sets of operating conditions. Therefore, initial verification of Tasks 2.1 through 2.3 does not release the contractor from responsibility for subsequent malfunctions that occur, solely as the result of these tasks, during the term of the contract.
- 5.6. The TRCO will have final responsibility/authority for determining whether or not each task has been successfully completed.

OBSOLETE OPTIONS

The contractor is not required to test the following options for compatibility with the modified AEM resulting from the proposed contract:

AALT	BIGF	DTQ	MEI	NTHPEN
ABORT	BISL	DUAD	MHARDD	THPPEN
AC	BN	EHINFO	MHEDGD	NTHSAM1
ACAV	BUDGR	EPAQ	MINR	NTHSAM2
ACEP	BURST	EPDI	MONTE PRINT	NTHSAM3
ACTUAL	BXCOD	EPIK	MPEND	NTHSIG
ACVO	CDK	FDIS	MRLD	NTHTNUMB
AD	CEPR	FLA	MSIGD	NTHTTYPE
ADC	CFVAL	FLP	MXINTG	NTHVAL
ADCAV	CFIXI	GDM	MYLDD	NTHVFACT
ADCN	CHL	HARDR	NAMBOM	NTHVS2
ADDEF	CODEF	HEDGR	NDA	NTHVS2
ADHARD	CRITKILL	IDAM	NDOC	NTHVS3
ADPC	DAV	IFIGHT	NDOCA	OBJ
ADPD	DDIV	INEROR $\neq 0.\frac{1}{4}$	NDOCS	OBJA
ADPK	DDOWARN	INK	NDOCX	OBJP
ALINFO	DEFAB	ISLE	NDOCW	OLAP
ALTA	DEFISL	IZONES	NDP	OWARN
ALTP	DEFLR	LENGTH	NEWC	PAQ
AREAR	DEFLX	LORDA	NSEGD	PAQA
ARL	DEFR	LORDP	NTHAREA	PAQP
ASM	DEFS	LPEN	NTH ATTACKER	PASM
AVE	DEFSB	LTQ	NTHBTARGT	PASS
AWH	DEFT	LWTG	NTHCDL	PC
AYLD	DELAY	MAPD	NTHCVT	PCAV
BDE	DMGR	MBUDGD	NTHGPRED	PDI
BDIV	DPI	MCEPD	NTH GREATR	PDIA
BFB	DRL	MDEFLO	NTH HARD	PDIP
BFX	DSMCON	MDMGD	NTH NTARGET	PDK

PWFF	SIGR	XCODEF
PEN	SIPL	XOBJ
PENEX	SLPS	XPAQ
PENR	SMALB	XPDI
PIK	SMALF	XPIK
PIKA	SMASK	XPVO
PIKP	SPIKA	YLDR
PRECOM	SPIKP	ZONES
PRL	SPIK1	
PTS	SPIK2	
PWH	SPIK3	
PXOBJ	SRANGE	
PYLD	SSIZE	
REFIRE	SUB	
REDOC	SUBD	
REDOCA	SUBN	
REDOCP	SVEL	
REMAIN	SWATH	
REPTOL	TASK	
RESF	TBR	
RHO	TDK	
SAMAV	TGTZONE	
SAMERF	TIM	
SAMRL	TISLANDS	
SAM1	TPASM	
SAM2	TQ	
SAM3	TURN	
SATH	VOK	
SCALE	VELA	
SEARCH	VELP	
SGPA	VQ	
SGPD	WDEF	
SGPI	WHLD	

SAI - STONEHOUSE

STATEMENT OF WORK

1. Objective: The objective of this effort is to improve the quality and efficiency of AF/SASF strategic analyses by modifying the Arsenal Exchange Model (AEM) to process problem statements of increasing scope and detail and expanding analyst control over allocation and output processes.
2. Tasks: In pursuit of this objective, the contractor will perform the following tasks:
 - 2.1. Expand the maximum permissible number of weapon classes, hedges, and target classes in the AEM to 50, 40, and 400, respectively. This task must be accomplished without adversely affecting the run-time efficiency of the AEM.
 - 2.2. Incorporate into the AEM an accounting facility which allows the user to create or define the same type of output summaries as can currently be created or defined using the AEM hedging capability. This new accounting facility will utilize formats similar to the existing hedge facility; will be completely separate from the existing hedge facility, to the extent that it will not affect the allocation process; and will permit specification of up to 100 accounting requests.
 - 2.3. Expand the AEM to allow the user the option to completely specify the set of targeting strategies to be presented to the allocation process. In addition, ambiguous constraints should be resolved prior to entering the linear programming portion of the allocation process. The specification methodology should be similar to the process used by the SWADE model. Output routines should be modified to indicate the permissible strategies resulting from the intersection of specifications via this facility with those of all other strategy specification facilities. In particular, hedge specifications that are unattainable because of conflicting specifications should be identified, to the extent possible, in the output print. The contractor must receive TRCQ approval of the proposed implementation of this task prior to actual implementation.
3. Deliverables:
 - 3.1. The contractor will deliver software for Tasks 2.1 and 2.2 within two months of contract initiation.
 - 3.2. The contractor will deliver software for Task 2.3 within five months of contract award.

- 3.3. The contractor will update the current documentation to reflect all changes and enhancements developed in support of this effort. Documentation will be prepared in accordance with "AF/SA Guidelines for Documenting Computer Simulation Models", January 1981. SAI will provide this manual to the contractor.
- 3.4. The contractor will deliver written monthly progress reports to include at a minimum (1) progress toward completion of specified milestones; (2) cumulative cost and projected funding for the coming month; (3) deviations from the task schedule; and (4) status with respect to contract objectives.
- 3.5. A final technical report will be delivered at the end of the performance period summarizing the effort.
4. Compatibility with Current AEM Capabilities: In accomplishing the tasks described in paragraph 2., the contractor is not required to insure that the options listed after the SOW are working. However, the basic code for the options should either remain in the AEM or be removed in modular form so that, if the need arises, minimal effort will be required to adapt the obsolete options to the modified AEM. Aside from these exceptions, all tasks will be accomplished without degradation of the current AEM capabilities.
5. Verification: The following verification procedures will be used to determine whether or not the tasks described in paragraph 2 have been satisfactorily accomplished:
 - 5.1. Initial verification of successful accomplishment of Task 2.1 will include evaluation of the results of at least two, but no more than eight, test cases designed to test the expanded weapon-, target-, and hedge-handling capacities of the AEM. The contractor will design the test cases by expanding, through duplication or subdivision, the number of weapon and target classes from one or more base cases provided by the TRCO. Verification requires that the solution for each test case be the same as that of the base case from which it was generated. The TRCO will design the base cases to exercise the expanded hedge capacity. In order to verify that capacity expansions have not adversely affected model efficiency, the CPU time required to process the base cases on the upgraded version of the AEM must not exceed the time required by the original (or pre-upgrade) version.

- 5.2. Initial verification of successful accomplishment of Task 2.2 will require using the new accounting facility to produce summary output identical to that producible using the current hedge facility. Working with the TRCO to design appropriate test cases, the contractor must also demonstrate the capability to simultaneously honor up to one hundred accounting requests.
- 5.3. Initial verification of successful accomplishment of Task 2.3 will include at least two test cases demonstrating general allocation control, cross targeting, and unambiguous constraint resolution. The contractor will provide the test cases which will be subject to TRCO approval.
- 5.4. It is virtually impossible to test new features under all possible sets of operating conditions. Therefore, initial verification of Tasks 2.1 through 2.3 does not release the contractor from responsibility for subsequent malfunctions that occur, solely as the result of these tasks, during the terms of the contract.
- 5.5. The TRCO will have final responsibility/authority for determining whether or not each task has been successfully completed.
- 6.0 All deliverables will be made to:

Science Applications, Inc
Stephen Garrett
7935 E. Prentice Ave.
40 DTC
Englewood, CO 80111

Section 3
DESCRIPTION OF WORK ACCOMPLISHED

As described above, the work accomplished falls roughly into these areas:

- 1) Expansion of AEM dimensions.
- 2) Incorporation of accounting hedges into the AEM.
- 3) Incorporation of the capability for the user to specify strategies for the allocation process in the AEM.
- 4) Providing general training, maintenance and data base support for the AEM, PACER, GROSA and SOSAC models.

Each of these areas will be described separately. This report intends to outline the nature of the activities undertaken during the period of the contract. The method of description will be to refer to specific sections of the user's manual and other reports when possible.

EXPANSION OF AEM DIMENSIONS

Within this task, the dimensions of the AEM were greatly expanded. The resulting model is capable of executing much more detailed cases. This modification now allows the AEM to treat cases which are termed mid-level model size and were formerly out of reach for the AEM. In order to allow these expansions, a number of changes to the AEM were required. They involved disabling some options which were using a great deal of space and not being used. The nature of the disabling was to remove the capability as a module which can later be returned if needed. Several other minor modifications were made to the AEM as a part of this task. These other changes were deemed desirable due to the large number of weapons and targets in cases now being run. Weapon and target names were expanded from four characters to twelve characters. Also, the column generation process was rewritten to accommodate the increased problem size.

The increased dimensions are as follows:

<u>VARIABLE</u>	<u>OLD DIMENSION</u>	<u>NEW DIMENSION</u>
Weapon types	30	50
Target types	70	400
Hedges	20	40
Accounting Hedges	0	100

A full explanation of the increased capability of the AEM appears in Reference 1, the AEM User Guide.

INCORPORATION OF ACCOUNTING HEDGES

The capability within the AEM to specify allocation objectives and perform accounting of force achievement was expanded under this task. Specifically, the HEDGE input variable was generalized to allow users to specify accounting conditions that they desired. For example, a user might wish to know the number of ICBMs that were allocated to economic targets. There is no way for a model to anticipate this type of accounting requirement. This modification to the AEM made this a simple input change for the user to specify that this calculation be produced in the output. The specification might be as follows:

```
ACCOUNTS=1,  
ACCOUNT(1)=WEAPONS ALLOCATED TO TARGETS OF TYPE (32) BY  
WEAPONS OF TYPE (ICBM) MUST BE EQ 2,
```

This capability represents a major step in freeing users of the AEM from hand calculation based on the output of AEM runs. Further explanations of this capability appear in Reference 1, the AEM User's Guide.

USER SPECIFIED STRATEGIES

Use of the AEM has changed somewhat over the years. Originally it was a very aggregated model designed to only answer very "big picture" issues. Over the years, the powerful mathematical techniques have caused it to be increasingly used for more detailed looks at force capability. With the accomplishment of Task 1 (increased dimensions), it was virtually assured that AEM will be useful for more detailed looks at forces. This increased capability within the AEM has been concurrent with a general trend within the community to look at more detail and more operational targeting considerations when performing "big picture" analyses. This is at least in part due to increased awareness of the operational issues associated with force use and at least due to the increased power of computers and mathematical techniques which allow models to now address more detailed issues.

This task recognized the issues described above and the need within the AEM to allow users more control over strategies used by the model. Two basic types of user supplied strategies are allowed. The input form for both are very similar, but the use within the code is different. The first type of user supplied strategy is termed a "must do" condition. This type of condition must be accomplished by the AEM (provided enough weapons and/or targets exist). For example, the user can specify that AEM must attack all SS-18 targets with 2 Minuteman warheads cross targetted with 1 ALCM warhead. The second type of user supplied strategy is termed to "can do" condition. With this condition the AEM can choose to not use the strategy, but if the target specified is attacked at all, it must be done with the strategy as specified by the user.

Further explanations of this option are available in Reference 1, the AEM User's Guide.

GENERAL SUPPORT

A great deal of general support and maintenance was provided during the period of the contract. The outputs from this task probably provided the Air Force with the greatest near term payoff. The majority of this work was in response to specific study requirements. General discussions of study needs and/or problems were translated into minor modifications to the models to perform new or modified calculations. The modifications made within this task tended to be small in nature and thus not amenable to reporting in this document. Some representative modifications were:

- Allow MOD files in the AEM
- Allow multiple misestimates
- Incorporate SAC damage functions
- Incorporate preliminary capability of collateral damage
- Expand definition of IMPACTS flags
- Expand TIE logic to allow proportional weapon tying
- Incorporate probability of arrival input variable
- Incorporate simple geography capability
- Speed up calculations in certain areas

All of these modifications were documented in Reference 1, the AEM User's Guide.

Support for the PACER, GROSA and SOSAC models was provided by SAI/Pentagon on-site personnel. As of 11 April, 188 hours of technical support had been provided.

REFERENCES

1. Bozovich, J.F., Cotsworth, W.L., Garrett, S.D., and Groover, P.L., "The Arsenal Exchange Model Handbook for the Modified AEM-HEDGE Version 82", S-82-005-DEN, March 1982.
2. Battilega, J.A., Bozovich, J.F., Cotsworth, W.L., Pietrewicz, P.A., "System Level Documentation of the Arsenal Exchange Model", S-82-006-DEN, April 28, 1982.

